The Window on the Soul
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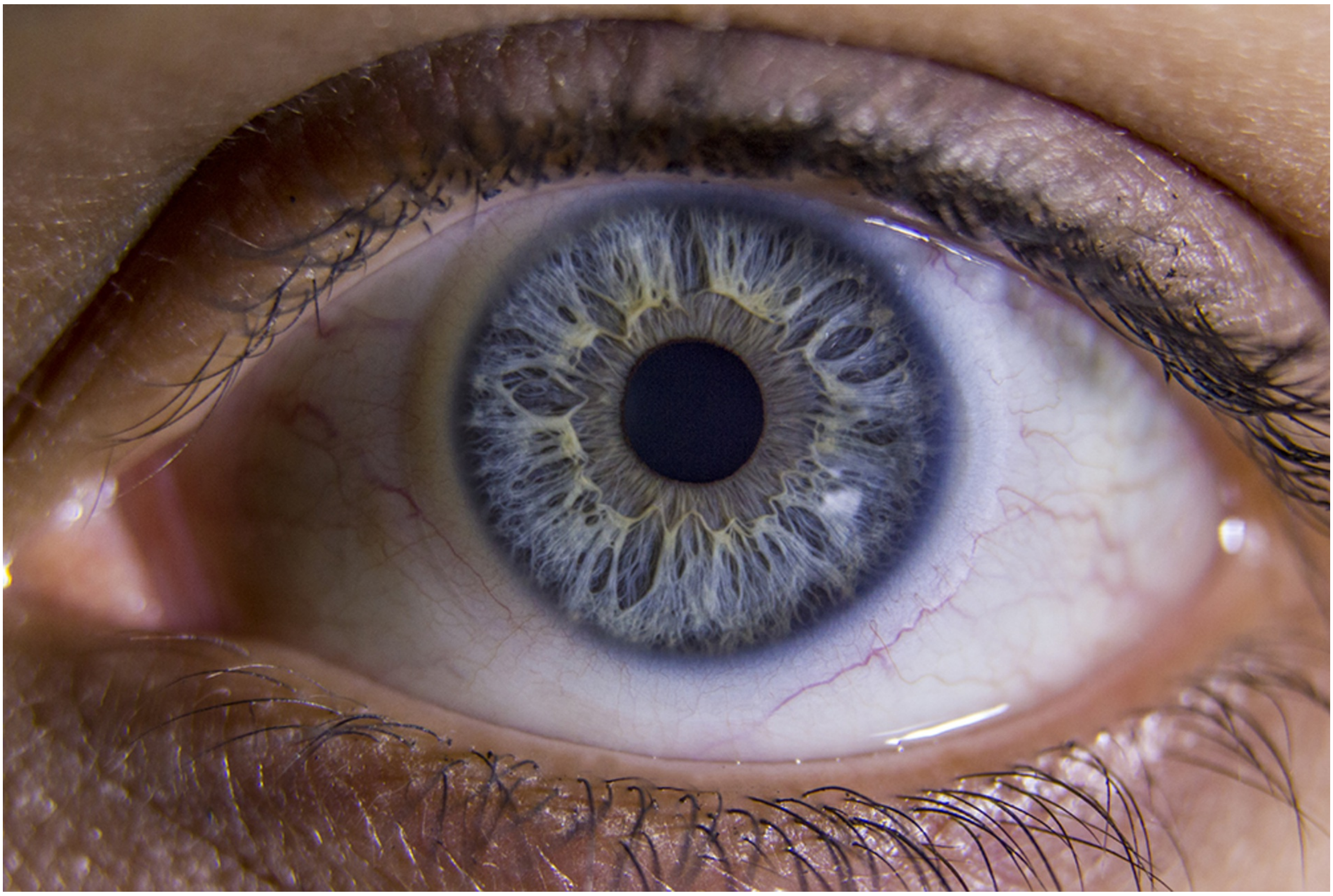

29 May 2013

The Window on the Soul

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Ladies and gentlemen, good evening and welcome to the final lecture of this series, which has been concerned with the philosophical and cultural aspects of the eye and vision. This lecture is a summary of the last dozen or so lectures that we have given and a very personal view of what vision and eyesight is all about.

I was asked to talk "The Window on the Soul" and just the title created a number of interesting conversations, whether it was "Window to the Soul", "Window of the Soul", "Window on the Soul", and our esteemed Professor of Rhetoric explained that it has to be "Window on the Soul", so that is the final version for tonight.

The picture that you see here was drawn by Leonardo and we will come to it later in the lecture, and it is actually "The Window on the Soul" as it was described by him.

In the very beginning, it was thought that it was just darkness, and as is described – this is the King James translation – it says that: "God created the Heaven and the Earth, and the Earth was without form and void, and darkness was upon the face of the deep, and the spirit of God moved upon the face of the waters and God said "Let there be light," and there was light. God saw the light, that it was good, and God divided the light from the darkness, and God called the light "day" and the darkness, he called "night", and the evening and the morning were the first day."

George Berkeley would disagree with this literal translation, and he says: "It is indeed an opinion strangely prevailing amongst men, that houses, mountains, rivers, and in a word all sensible objects have an existence, natural or real, distinct from their being perceived by the understanding. Familiar objects, like table and chairs, are only ideas in the minds of perceivers, and as a result, cannot result without being perceived." So, what he is saying here is the Big Bang could be created, but there was no light until there were organisms and structures that could see light, and in fact, the Earth and everything around it, and the Universe, is dark, unless eyes exist.

From this very soul of the subject, I think we come to the point of that saying, that the eyes are the window of the soul.

Furthermore, "Esse est percipi": "to be is actually to be perceived".

Ronald Knox created a rather nice limerick:

"There was a young man who said "God
Must find it exceedingly odd
To think that the tree
Should continue to be
When there's no one around in the quad."

I am going to talk about windows and lights and where this ancient saying comes from. Interestingly, it is not Shakespearean. It is very difficult to get to the root of it, and perhaps we have to go to Cicero: "Ut imago est animi voltus sic indices oculi"; "The face is a picture of the mind as the eyes are its interpreter".

Thomas Phaer, who was a paediatrician, translates this book on the right – it has been translated from Latin into French, and he translates it from the French into Elizabethan English: "The eyes are the windows of the mind, for both joy and anger are seen through them." That is the "Regiment of Life".

"These lovely lamps, these windows of the soul," taking it from this by Joshua Sylvester, later on, in his "Divine Weekes and Workes":

"The eyes are called the windows of the heart by which love enters the same", was an Italian version of this. In French, interestingly, rather than the heart being the window of the soul, the eyes were the mirror of the soul.

"You cannot hide the soul. Through all his unearthly tattooings, I thought I saw the traces of a simple honest heart; and in his large, deep eyes, fiery black and bold, there seemed tokens of a spirit that would dare a thousand devils." This is Herman Melville in "Moby Dick", describing Queequeg.

So, I think we will leave it to another American: "Who are you going to believe, me or your own eyes?" Well, let us see…

God's light is the important thing we are talking about here. There was a translation of a Pseudo-Dionysius manuscript which led to Abbot Suger, friend of Louis VI and regent to his son, who, when he reconstructed the choir of Saint Denis, as you can see on the right here, the lovely Benedictine Priory in the outskirts of Paris, he glazed the upper choir with beautiful blue glass, called the Nova Lux. Now, this stained glass was terribly expensive. It was made out of the crushed up teseri of old Roman and Byzantine mosaics, and these themselves were made from lapis lazulis, which then, as now, only came from one source, and that was in far-off Afghanistan, which was as warlike and lawless then as it is now. This expensive pigment became known as ultramarine, "from beyond the seas".

It was believed that the primary light, lux, is a substance distinguished from light of heavenly bodies, which is lumen that flows from it. Lux is so perfect that it exists only with God and we can only see it as we become one with God, but God allows lumen to come out to illuminate our world and allow us to see his great works, so lux is very closely associated with divinity.

This comes from this mistranslation of Pseudo-Dionysius in the 5th Century. It is an anonymous theologian and this manuscript was given to Louis the Pious by Michael the Stammerer in 827 at Compiegne. It was badly translated. The best Greek translators of the period were actually in the Anglo-Irish monasteries in the isles of the Northern Sea, formerly known as Great Britain or the United Kingdom, and also Ireland.

Now, John Scotus - Scotus was the term used for Irish – was invited over to translate this properly, which he does, and after some hard work, he is invited to a large dinner, where the King leans across the table and says "Quid Distante inter Sottum et Scottum?" "What is the difference between an Irishman and a drunk?" And John Scotus leans over and says, "The width of this table, Sire." But because his translation was so good, he got away without a whipping or worse.

Blue light becomes important to illustrate many things in this period. In fact, this is the most colourful period of stained glass in Western ecclesiastical art.

The eye is important for this divinity, for seeing this light. It is this window through which God's works are made manifest to us, so an enormous punishment is to remove the eyes, and there are many biblical examples that I have spoken about before, but I thought this one was rather interesting, which is the story of Eilward of Westoning in the North Aisle of the Trinity Chapel in Canterbury Cathedral, this beautiful window. Parts of this window are related, in a comic-strip fashion, with the story of Eilward, who was owed money by Faulk, who was another indentured labourer who had got some land, so they retire to the pub, as is the English fashion, as is quoted in the text. During that period, some argument develops. Essentially, Eilward said "I will pay for the beer if you pay what you owe me, and everything is quits." The argument develops, Eilward leaves, in a temper, and on his way home, he pops into Faulk's house and steals a pair of gloves used for ditching. Unfortunately for Eilward, Faulk's children are at home and run back to the pub and say, "Dad, Dad, you know your mate? Well, he has just stolen your ditching gloves!" "Right, we will have him!" They go round to his house, they beat him up, and they drag him back to Faulk's house, where they call the magistrate, who says, "Come on, it is a pair of gloves – calm down!" So, the children nip into the house and produce an axe, a stone, and a couple of shears, and say, "Well, actually, it is a bit more serious than that," and yes, this is now an indictable offence. So, poor old Eilward is carted off to jail, where he remains for some while, until the Assizes come into town. Unfortunately for him, there has been a change in law because of the Assizes of Clarenden, and no longer is he going to be tried by his contemporaries and a jury. He is going to have the new-fangled system from Europe, and European law at that stage was trial by jury, so his hand was plunged into the boiling water, he seized the red-hot iron, and took it out. His hand was then bathed and wrapped in cloth. Three days later, in front of the altar, it was unwrapped, and unfortunately for him, it has festered, which meant that he was guilty. So, he was taken out and, in front of the magistrate here, wearing his white cap, he has his testicles and genitals cut off, in front of his eyes. His eyes are then gouged out and he is then cast out to fend for himself as a blind beggar.

At sleep that night, St Thomas appears to him in a dream, and he paints the sign of a cross over his head with his crosier, and his membra swell and his sight is restored. We see him here going round the village, pointing to his eyes, giving money to the poor, with an enormous erection, disguised as a tree behind him.

Now, this is a rather unusual miracle since it depends on the appearance of St Thomas. All the others, St Thomas miracles, were of the blood cult. When Thomas was killed, he had the back of his head cut off, and an enterprising monk scooped up the blood and the brains and put them into a bottle, and when you went to the shrine, you were given little bits of this on a silver spoon or a biscuit, and then you donated some money and whatever you wished for became true.

Unfortunately, there were several problems with this: one is that it is disgusting; two is it is slightly heretical because of the blood of Christ; and three, there is this problem of supply because, with the European wars, Canterbury becomes a major centre of pilgrimage for much of Northern Europe because they cannot get to Santiago, to Compostela, and in fact, the setting up of several priestly nightly orders to protect these pilgrim routes was necessary before St James could become open again. Thousands of people were coming and they were running out of blood, so they hit on the brilliant idea of dilution, and then they diluted it in wine and there was enough to last them till 1543, when Henry VIII despoiled and stopped the party.

Eyes themselves are windows to the person's body and their soul, not just in a metaphysical way, but actually in a very real and practical way. Originally, there were very little ways that a doctor could get access to what was going on inside the body. He could examine the skin, he could feel the pulse, he could look at eye discolouration, he could look at the tongue, he could examine the faeces, and in particular, he could examine the urine, which he looked at the turbidity, how opaque it was, and what colour it was. These original colour charts, one of the first graded colour charts in the world, were used for examining and diagnosing the urine, and then diagnosing the patient's mental health amongst their other things, including their general health.

This was a process that went on for many, many centuries, and even here, in the late-seventeenth century, we see the doctor examining the urine phial. This was condemned by many physicians, particularly those not in Europe, particularly those cynics who resided in that cold, wet country across the North Sea, and Thomas Brian publishes a pamphlet called "The Pisse-Prophet or Certain Pisse-Pot Lectures", which I think you can get the tone that he was thinking, that this, compared with an astrological chart, was insufficient to make a diagnosis of what was happening to a poor patient.

In the absence of having more exacting to make diagnoses - remember that the stethoscope, the ophthalmoscope, all of these things we take for granted nowadays, are hundreds of years in the future. What else can be looked at? Well, one of the things that can be looked at is the eye, and the most obvious part of the eye to look at is the iris, this most beautiful structure that is created with lots of different crypts and folds, and everybody has an individual iris. It is so individual in fact that you could distinguish two identical twins apart because how this forms is reliant on genes but the final bit is chaotic as it disintegrates.

Iridology is used as we go through American customs. Way back, Ignaz von Peczely had tried to catch a bird when he was little, an owl, and accidentally broke its leg, and he noticed that a flash appeared on the iris. Later on, as a qualified doctor, he was setting the leg of someone, and during the period of healing, he noticed another flash, in exactly the same place that his owl had a flash. So he then proposed that one could diagnose what was going on in the body merely by looking at the eyes, so the eyes had really become a window of the body and also of the soul.

Individual variations between iris could tell you what was going on, and down here is the kidney and so on, and this system for diagnosis has lasted and come through in alternative medicine through to today, and here is Dr Berkeley-Digby's analysis of somebody's eye here. He says: one, there are many weaknesses or openings in the iris, these iris crypts, so this a problem with atonic bowel from chronic constipation; there are concentric rings, here, which are stress rings, and this is a tense or nervous subject, so we are using the eyes as a window on the soul, on the mind. Here, he says muddy deposits indicate problems with the lymphatic zone and unhealthy cholesterol.

Unfortunately for this system, we have yet to find robust evidence where two observers can agree and whether they can actually, more than chance, make a diagnosis, and several studies have been done to date. Now, the iridologists of course accuse the doctors of fixing it and not doing the right study. Nevertheless, the doctors themselves are saying we would use iridology because it would be rather nice, and it is non-invasive and we do not have to do blood tests, and we do not have to stay up late at night, and it is expensive and we would get paid a lot, so it is all good ideas to do it – the problem that we have with it is we do not see any robust evidence that it works. So, at the moment, that is the status of iridology.

In come the psychologists at Orebro University in Sweden, where they did 428 subjects, and they looked at their personality traits, and they compared them, unbelievably, to the structures in the iris, and what they found was these patterns in the crypts and these contraction furrows actually related to the personality traits. Those with densely-packed crypts were more warm-hearted, tender, trusting and likely to sympathise with others; those with more contraction furrows, around the edges, they tend to be more neurotic, impulsive, and likely to give way to cravings. So, they thought the eye structure and personality could be linked.

This may not be as crazy as it looks, and it turns out that the control genes that control eye formation are also involved with controlling the front part of the brain – in fact other parts of the brain as well, but particularly in this area, and they are switched on very early, at this tadpole phase. Here are the eyes forming when the brain is very, very rudimentary, and then, later, it folds up to create all this, which packs in all that area of cortex that we need to process, mostly the visual world. The bit we use for vision is over half of our brain. The bit we use for maths is probably about the size of your fingernail, and that is why vision is easy and that is why Maths and French and things like this are hard – except if you are French, when it is easy.

These things are control genes, and the PAX-6 gene makes this protein, and we are going to hear about PAX-6 later on, so I thought I would show you what it does. If you have got a length of DNA here, and here is the gene, all this bit, in the olden days, was considered to be rubbish. It is not rubbish DNA; it is actually really, really important, and on it, you have sites where things start to attach, which enables the DNA to fold around this protein, which then allows the gene to become active and to be transcribed and to make little copies that are going to go on and eventually make proteins from this gene. PAX-6 is a particularly important gene for making these control factors, and it is the gene that is concerned with the assembly of the eye and also with the assembly and controlled assembly of the brain. It does not switch on just willy-nilly; it switches on at very important particular moments, and in particular places, to enable this beautiful structure of the eye to develop, and not only in humans, in mice, in zebra-fish, even in flies. In fact, in every animal so far we have discovered, they have these master control genes, and they are all related, and since these animals diverged from each other over 500 million years ago, particularly jellyfish and the later line that was going to go on and form backbones and become us and other animals, it would appear that in fact the eye and the assembly of the eye comes back to a single invention. It may not have been separately invented many, many times. It may just have been invented once, and the diversity then of eyes, and the different sorts of eyes – because, clearly, a drosophila has a very different eye from a human or a zebra fish – must then be explained.

Now, the second thing that happens here, if you mutate this PAX-6 gene, you end up with abnormal eyes. You end up with a disease called aniridia, where they do not make a proper iris and the front of the eye does not form well. They do not make proper stem cells. The surface of the eye becomes cloudy and opaque. The same happens with a mouse. The same happens with a zebra fish, where they end up with a small eye and a poorly seeing fish. In drosophila, you end up with no eye at all, so it is very fundamentally important to not have mutations in that gene.

This is what aniridia can look like. There are many different varieties. You can actually end up with no iris at all, you can end up with partial iris, and I will show you some clinical cases later on.

This is a regulator for coordination and pattern formation. It is responsible for instructing the cells in the embryonic period to differentiate, that is to become brain and eye cells, and make the pattern.

So, I am interested in the iris, and abnormal irises are very important because they are part of our soul. If you have an abnormal eye, particularly if you have blue eye, it becomes a very obvious and noticeable defect, so you have horses shying in the street and children pointing at you, and eventually this becomes upsetting and you find you want something doing about it.

It is rather difficult to sew up these eyes because if you go inside with the needle, you are going to scratch up the inside of the cornea, so various techniques, that is mechanical suture have been developed, where we are just on the outside of the eye, and then we tie it up neatly and end up with a nice round pupil and one happy patient.

This is me doing precisely that. I am not going inside the eye at all. It is all on the outside of the eye, and then it is tied off through a tiny little incision here, and there is a round pupil in someone who would had cataract surgery done but, unfortunately, they had also had the iris caught up in the machine, which had led to them having a very big and bad iris defect.

Some people have even more severe defects, and here is someone who had a massive injury, where they have lost their intraocular contents and most of the iris, apart from a few cells plastered on the cornea here.

A similar event with this chap with the blue eye…

There is a new technique here, using what is called a Dr Schmidt iris. What we do is, we take a photograph of their fellow eye, we send it off to the lap, where it is painted and etched onto a biocompatible material that we can then inject - here is the incision site, which is 1.6 millimetres – into the eye to reconstruct their vision and the appearance of their eyes. This is the pre-op and this is the post-op. This is the right eye, this is the left eye, and you can see we are giving him a much more naturalistic appearance between the two eyes, and furthermore, we are giving him vision.

So, that is the iris, and we have demonstrated that the iris gives us some information about what might be going on in the inside of the body, but unfortunately very little. I am actually a uveitis specialist and, under the microscope – I will not bore you with it – we can actually diagnose many things, from syphilis to sarcoid to TB, by looking at patterns of granulomas on the iris, but that is not what was originally meant by iridology.

We need to go beyond the iris, we need to go into the eye, we need to go into the retina, to really find out what is going on. The problem with going into the retina is it is very difficult because your head gets in the way. When you shine a light in the dark and you see a reflex from cats or other nocturnal animals, it becomes quite apparent that this is actually not them sending light out, as was formerly believed, it is a reflection from the light going in. But if we then move our heads to stand right in front to look in, we block off the light coming out and we cannot see anything. So, what we have got to do is to work out a way of indirectly illuminating the retina from the side, or we can stand to the side or use a prism to do the lights to move it, and this was invented by Charles Babbage. Unfortunately for Charles Babbage, who also invented the first computer, he gave it to an ophthalmologist, and the ophthalmologist had a look at it and thought, “That is quite cute, mm, not very interesting,” and did nothing with it, which meant, worst of worsts, over three years later, Hermann von Helmholtz, brilliant man, he invents an ophthalmoscope, and although this said this was only in use until the 1920s, it was not – this was used on the wards, on a daily basis, when I was a junior doctor examining the post-ops/post-docs. We did exactly this, using a bright light source and a twenty diopter condensing lens to view into the eyes.

Using this miraculous invention, they certainly were able to look into the soul and into the body. There was a disease where the eye looked normal but they were blind. This disease was called amaurosis and nobody knew what caused it. One of the commoner causes was a disease called glaucoma, and they could now look in and see this terrible pale nerve, completely cupped out and dead, so they could diagnose glaucomatous optic atrophy.

Here is a nice healthy nerve that is pink. The problem here is the centre of vision is not very healthy due to these yellow deposits of fat from leaky vessels in a patient who has diabetes.

This patient has folds – and this is a nineteenth century drawing – of a retinal detachment.

They could diagnose a lot of these things, but they could not really treat them until the twentieth century, but nevertheless the stage had been set.

We can actually look in the eyes and diagnose strokes. Here is someone who has got a field of vision missing and it is due to a blockage in this artery, where a little bit of cholesterol plaque has been flung off, and you can see it, and the artery downstream is not carrying the blood to this retina, which has stroked-out. This is very serious and requires significant treatment to prevent the patient becoming significantly ill from other complications and strokes elsewhere.

We can even diagnose new blood vessels, using photographic techniques combined with ophthalmoscopy, and these wide-film angiograms are becoming more popular now. This is the latest state-of-the-art, and we can see way out into the mid-periphery. We can see there are no blood vessels here. Blood vessels are where it is white, and this is the normal capillary network. There are no capillaries here, so the body response is to release a chemical called VEGF, vascular endothelial growth factor, which then chaotically makes these vessels, and the problem with these vessels is they leak, and they leak blood, and that means people can go blind. We have numbers of treatments for these.

We have now looked and seen that the eyes possibly could now be a window on the soul. How do these windows work? What is this all about? How did they start?

You remember, at the beginning, I said there had been the Big Bang and it created lots of electromagnetic radiation and all sorts of things, like stars and so on, but it did not create light. To create light, we needed something to see it with, and this is the story of how that happens.

Originally, these light-sensing molecules developed. They were not used for seeing for a billion and a half years. They were used for other things, locomotion amongst one of them. Eventually, these got incorporated into specially folded membranes, so you can have lots and lots and lots of them, which means you can do what is called photon-capture. You can capture one packet of energy and, next to it, another packet of energy, and add it all up, until you have enough packets of energy captured to make this cell respond to allow chemicals to flood into it. Now, the problem with that, it is a bit chaotic because it can have light come into it from all over, particularly if you are a transparent animal in the primeval soup, so what you want to do is to shield it, so we get directional light responses. You can do that with a little bit of pigment around here, but better is to shield the whole cell with a separate cell called a pigment cell, and the thing that you will see in all developed eyes is this association with pigment shielding and the receptor, and then we can develop some structures within the eye that are going to help us make it eyeball-shaped, and we want some nerves to transmit it away, and then, finally, we end up with this beautiful sophisticated structure, and there are varieties of these beautiful sophisticated structures.

So, originally, if they were not used for vision, what were these molecules used for? Well, 3.8 billion years ago, once the Earth had actually cooled down enough to allow liquid water, it was still a fairly inhospitable place. It was hot. The atmosphere was carbon dioxide, nitrogen, methane – there was no oxygen around. There was an intense ultraviolet irradiation from a very young dim Sun. There were lots of volcanoes, lots of meteorites bombarding. Now, in this so-called inhospitable environment, fats started to be laid out on clay, and they combined with sugars and proto-molecules, called amino acids, to form little bags, and these little sugars become self-replicating – so not life as we know it, but it is the start. Eventually, they make a ribosome, which is a small nano machine that can do this terribly, terribly efficiently.

A very, very long time ago, 3.5 billion years ago, we start finding these things, called stromatolites, and this is the fossil evidence of these stromatolites, which are single-celled microbes in colonies, and they still exist. They existed then and they exist now. This is Australia, so when we are playing the Ashes, we have to remember this, and we realise that life down in Australia has gone on a very long time.

These organisms used molecules to use the electrochemical to convert light from the Sun into electrochemical energy, and if you can do that, you can use it to pump in a proton, a hydrogen, and then you can attach it to a little motor, and then you can go up and go closer to the Sun. Now, remember what I said about the Sun, it's full of UV, so you do not want too much UV, so once you have sunbathed enough up here, you go all the way down again, using another motor that turns it round the other way, and if you do not believe me that these things exist, here is a little photon micron of them. They used three types of pigments: they use chlorophyll, which we are familiar with, which is why trees are green; they used cryptochromes, which use blue light to repair the DNA and the RNA structures within them, and now, maybe involved, there is a magnetic field detector in the retina that may allow us to get home from the pub and birds to fly south in the summer and so on; and then rhodopsins, which are the interesting ones, because, ultimately, although they are not used for vision in these animals, they are going to be co-opted and used for vision, in single-celled animals, when these become invented, called eukaryotes, which is the acquisition of a nucleus to form these eukaryotes.

These are the old archaic organisms. We now call them extremophiles. They would be most upset if we called them extremophiles because they lived in this lovely world that was hot, full of carbon dioxide, nitrogen and gorgeous, lovely things like that, and in fact, making oxygen as their by-product led to the extinction of many, many of them. Oxygen is extremely toxic, and in fact, it was the release of oxygen that allowed these organisms to come to the fore. They would swallow some of these whole and, very occasionally, would not digest them, and they became intracellular organelles, and eventually, some of these organelles can form vision-related structures, which actually have a focal length and focus, and focus onto layers of these photo pigments. So, this little critter, which is one cell, lives on the bottom of a pond, sees something go by, it nips up and it eats it.

It is quite possible that engulfing these eventually leads to the formation of the eye, as has been proposed, although that link is missing.

So, we can have different levels of vision. If we just want a non-directional light response, we just need a photoreceptor here, packed with chemicals that are going to sense light, and that can make us do things with our behaviour. It can make us wriggle away, if we are a worm, or wriggle towards the light if we want to. We could wriggle under a leaf if we do not like light. If we want direction, as I pointed out before, we need to add in some pigment cells. We can re-duplicate the whole lot and end up with compound eyes developing, as we come up to make them spatially aware, if we come into a pinhole camera. So, now, we are not seeing light from this direction, we are seeing light coming only from this direction.

And then, finally, if we want to have really good spatial vision, so we want to see the difference between stripes very close together, we want to read the bottom line on the chart in the modern world, we need to have some sort of focusing mechanism.

It takes a very short time to go from this. In fact, it is so short, it is very difficult to see it in the fossil record, and that is why the big period where we see lots and lots of different types of eyes, almost simultaneously, is in the Cambrian explosion, and the reason that they developed eyes then was because predators evolved essentially, and it is to escape predation, and as I pointed out before in lectures, lots of these animals without backbones, why do I study these things, why do I look at them, and why am I fascinated by them? Well, it is because they are delicious, and, unfortunately, lots of things in the Cambrian period found them delicious as well, so they invented eyes fairly rapidly to make sure that they could escape them and make the mechanisms for protection.

There are many different types. You can have single-chambered eyes, as we have said before. You can have eyes that have poor focusing mechanisms, using a complete intraocular solidification of the fluid into a gel, not very good for focusing, very, very poor. You can actually then start making things like corneas and having dual optics, which are very good. We use this, fish use this, and birds use this to get very high definition acuity. One that has lasted a very long time in nautilus is a pinhole camera, which is not very good at all – you know, two to three degrees is what you are seeing, and it is a fairly large thing has to come past before you can differentiate between two of them.

Here, this beautiful eye is a reflecting eye of the scallop and this actually has two retinas: one for everyday use that just tells you when things are floating by that might be big that might want to eat you; and another one, here, which is much more high-definition and can focus, because scallops, uniquely amongst the bivalves, have a jet-propulsion mechanism that enables them to move to different places, and the muscle that moves them is what we eat – it is the bit between the two bits of black pudding on top of the lettuce.

And here are these scallop eyes – you can see them. Are they not just so beautiful?

There is another lot, along here, single, pinhole eyes.

Many different types of eyes… These are trilobites, and they have compound eyes. So do insects.

Single-chambered eyes are used by mammals and reptiles.

This is strange, is it not? You would think it is a fish… No, it is not a fish. It looks like a fish. The reason it looks like a fish is because it lives in the sea and it has got to swim, and the sea is sticky, so if you want to swim, you want to be long, you want to be torpedo-shaped, and you need some stabilising factors along here. That is why this reptile looks like this mammal, which looks like a fish. This is called convergent evolution. Just because they look the same does not mean they are the same. They are not related at all.

Let us look at some eyes that we recognise. Here is a camera eye. Here is another camera eye. Here is another camera eye, with an iris and a lens. Here is another camera eye. None of these are related. This is a mammal, this is a fish, this is a jellyfish, and this is a squid, so completely different animals have assembled the same solution to seeing.

So, why do we have these different ways of looking? What it depends on, it depends where you live, and what you want. If you are a worm, you do not need to invest in an eye like this because all you need to do is to spend your life underground. You do not need light at all. If you are a surface worm or you are a velvet worm, you need to be able to differentiate between light and dark because you need to be living under the leaves during the daytime and out foraging at night-time, etc. etc. If you need to read Shakespeare, you need eyes like this, but if you do not need to read Shakespeare, you could probably have eyes like that and just go swimming and eat things and spend your life under the mangrove canopy.

In ancient times, looking at these eyes, as I said before, they believed that there was something within the eye that enabled you to see, and the light rays came out and illuminated the world, and if you put people's eyes out, they could not illuminate the world, they could not see, which was therefore proof of concept.

The other concept was this called eidola, which are little thin films coming off. We have got to imagine this like a snake, shedding its skin, and all the time, every object in the world was shedding these little bits of solidification that entered the eye and went into the seat of vision, which was believed, in those days, to be the crystalline lens.

A rather complicated theory, here, that was later taken on by Descartes and made a little bit more sophisticated was, in some way, when you turned your gaze onto something, you solidified the ether between you and that subject, which then created a vibration in the ether - later on, Descartes talked about the molecules vibrating - that could then transmit information from what you were looking at into your eye, and into the seat of the vision.

Nowadays, we know that that is probably not true and we know that cells are electric, but we still have a problem: how do you convert light to electricity? You need a photoelectric cell, and we call those photoreceptors, and it is a very clever mechanism, how it does it. When the light hits this derivative of Vitamin A, it changes its shape and releases the pre-enzyme to become an enzyme that then very rapidly takes out this molecule, called cyclic GMP. Now, if you take out cyclic GMP, you stop the normal flow of salts into and out of the cell, and this happens with a very short time. The cell polarises, and then it stops releasing its inhibitory chemical. Then you have got to multiply this many hundreds of thousands of times in each disc, many discs in each photoreceptors, many photoreceptors in each retina. So it is an absolutely beautiful system, and furthermore, we recycle this to save us having to eat Vitamin A all the time. Eventually though, the recycling fails and you do need to eat Vitamin A, and we all know, from childhood, that if you do not eat Vitamin A, you go blind.

Electricity in animals was discovered in Bologna by Luigi Galvani, who accidentally made a mistake during one of his experiments and got the frog's legs to move.

Now, Alessandro Volta repeated this experiment, and then worked out it was not the animal that was making the electricity. In fact, you could make the electricity outside, and this is the first battery, and then, if you applied this, the animal could move.

A synthesis to these views came with Giovanni Aldini, who actually was a nephew of Galvani. We use the term galvanism today – galvanise into action to make dead things move. Junior doctors, for example, when I was a junior, we would be galvanised by our bosses to go and do something.

Anyway, they used to do it on dead bodies, and then they thought, actually, what we will do is we will do it on real corpses, and they came over to London and they got a real corpse, and the applied the electricity and the face moved – he grimaced. He then moved his neck, moved his head, and turned it towards the audience, and opened his eye. At that point, several people fainted, and Mr Pass, the beadle of the Surgeons' Company ran home, where he promptly died of fright.

Further experiments were done. This is the one in Glasgow, where they were deliberately attempting to re-animate this person back to life. This is the corpse of Matthew Clydesdale. Now, the doctor here applies the electricity. The face moves, the head moves, they move it down onto the phrenic nerve, and he starts to breathe. Indirectly, they had invented the defibrillator as well, by using two electrodes on either side. People ran away in fear, and later, Mary Shelley is going to write "Frankenstein, the Modern Prometheus" and this is where this story comes from. There is a rumour that she may have attended the animation of the corpse in the Surgeons' Company Hall. Of course, these were open to the public. This was the first public execution they had had for ten years in Glasgow, but remember, with the Anatomy Act, that if two people were hanged on that day, one of them gets hanged and he is buried, but one of them was a murderer, so he is hanged and committed to public dissection to make sure that the sin of murder could be differentiated from the sin of stealing a sheep or whatever else you were hanged for in those days.

Now, how was this electricity generated? Well, if we just have a cell, we will have it bathed in salt solution, and there is sodium and chloride, as we all remember from primary school, and there is a couple of other ions here – the purple ones are potassium. If we sit there and there is nothing particularly going on, we will have roughly about the same amount of salt inside the cell as outside the cell. Ah-ha, but what happens is, we have a pump here that pumps sodium out, and pumps potassium in, so we end up with more potassium in the cell and more sodium outside, significantly more. This is inside the cell. We end up with 100 inside, just five outside, which I have tried to depict here for you, and outside, we have got 150 and we have only got fifteen inside, so very, very few. Now, while this is still electrically in balance, it is not in balance because there is now too much potassium, so the potassium leaks out to equalise the amount of potassium inside the cell as on the outside of the cell, and this now creates a charge. The outside of the cell becomes positive because potassium ions are positive; the inside of the cell becomes negative because chloride ions are negative and they do not leak out – and, look, we end up with a potential across the difference, where it is minus 70 milli-volts in here compared to outside. What happens when we have an electrical impulse is that we open the sodium gates, there is a flooding in of sodium, which now changes the balance and we get this spike. This happens over one-thousandth of a second and gradually moves down in a wave, down the cell, enabling us to transmit that information from the photoelectric cell, the photoreceptor, towards the brain, and we do this through the other structures in the retina, which is this beautiful… It is not a photographic film. It is this beautiful computer we can actually image now. This is what we call an OCT scan, and we can see all these different layers, and all these layers are doing different functions, with different types of cells, called bipolar cells, horizontal cells, amacrine cells, and there is different types of these, and some switch on and some switch off, to create processing that is going to compare relative brightness and to sharpen edge detection, and that information is going to be sent down digitally along these wires, called ganglion cells, to the brain.

Very interestingly, in the dark, these eyes are active, and in fact, if you shine a light on them, not a lot happens – you make them a bit less active. However, if you shine spots of light in certain areas, you will get a burst, but for this cell, if you shine a spot of light on it, it does not like it at all, but it does like it if you shine a dark spot on it – it fires very much; whereas, if you shine a bright spot on this cell, it switches off. So, there are two types of cells: some are responding eventually after this processing to light; some are responding to dark. Well, that sounds strange at first, but when you realise, if you are looking at this, there is as many dark things as bright things out there. In fact, this print is dark, the background is light, so you need to be able to differentiate dark and bright. It is not just about finding bright things.

This information goes back and it is crossed in a structure called the chiasm. Originally, it was thought stuff from the left side of the body went to the left side of the brain and stuff, information, from the right side goes to the right side of the brain, and the bit of the brain thought, until the middle of the 1800s, was thought to be the pineal or the mid-brain. It is called a chiasm because it crosses, and this is the chia, the chiaro, from the chiaro page made and illustrated by Eadfrith of Lindisfarne, and it is this beautiful “Christi autem generation sic erat”…”The birth of Christ took place thus”, but it is this beautiful illustration which, to my mind, is one of the major pieces of medieval artwork from the Western world.

This story is not correct. Although they called it a chiasm, it was right, it was an x, but what is happening in the x is the information from the right eye is not going to the right hand side of the body. It is the information from the right hand side of the body that is going to the left hand side of the brain, and information from the left hand side of the body is going to the right hand side of the brain, and so there is a partial crossing, as pointed out by Newton.

In fact, it is not quite as simple as that, as was pointed out by “Chevalier” John Taylor in a lecture at Oxford. He was the chap you might remember who drove around Europe in a coach and horses, six black horses. The coach was painted with eyes. All the horses were blind, except for one eye in the leading horse, allegedly due to him having practised on them. When he made a dance in Dresden, he had to change his shirt 21 times, having danced with all the eligible females, and left the next morning without paying the bill. Allegedly blinded Bach… However, had this brilliance, and why someone who was so hated by the medical profession? Well, he trained at Thomas’s, that might explain some of it, but nevertheless, he had this brilliant insight, and turned out, as we are going to see, to be correct.

So, where is this soul and what is the connection between the eye and the soul?

Originally, it was thought to be due to cisternae or lakes within the brain that are called ventricles, and this was eventually incorporated, after their discovery in animals, into medieval thinking, particularly by Albertus Magnus, and this is his fresco in Treviso, done by Tommaso da Modena, who, further down on that cycle, by the way, depicts the first example of spectacles and visual aids for reading in the world.

This complicated thing of different ventricles was then translated and made a lot more simple in the “Philosophy for the Simple” – I like that, I would have read that book myself I was around in the medieval period. What they did was to find out there are different processes, so you gather information from the senses, particularly from the eye, it then goes into the sensus communis, or what we now call common sense, and this is where we get that word from, and then images are created in the second cell, and finally, they are sent off to the fourth cell, where they are stored as memories.

Leonardo da Vinci…brilliant, fantastic dissector…does not quite get this one, and there is a reason he does not, and the reason he does not I am going to show you in the next few slides, and it is because of the way the brain was actually dissected in those days. But he has the eye here as the window on the soul – you can see a direct connection to these ventricles, to the first, where the information is processed, to the second, where it is digested, and these images are then stored in the third. He also made one called imprensiva, which has never been described before or since and was a sort of figment of his imagination.

The eye, which is the window of the soul, is the chief organ whereby understanding can have the most complete and magnificent view of the infinite works of nature. The ear, of course, comes second.

Now, how they dissected the brain, in those days, was they dissected late on. You did, first of all, the internal organs that were going to rot. The next day, after prayers, you did the muscles, and then, on the final day, you did the brain, and by the time you did it, it had gone to this mush. Even the great Vesalius did not add anything to our knowledge of brain structure because of this.

Here is, quite late in time, this is the anatomy lesson of Dr Deyman, and you can see he has been eviscerated first because that is going to go rotten. The next day, after prayers, they are now doing the brain, but the brain has already gone to mush at this stage, so we are not going to get much information.

Until you come to Gresham College, where, as you know, you get filled with lots of useless information, and occasionally some useful information, and here is a bit of useful information that came out of Gresham. Some while ago, my predecessor, Sir Christopher Wren, who was a great anatomist, had become familiar, he had worked out, long before we had the health fascists, that actually, if you have a lot of alcohol, you can preserve the brain. Now, what he was alluding to is, if you stuck it in a bottle of alcohol, you could do this, but he also worked out how to inject the arteries, and this is his illustration for Thomas Willis's great book, and it is the first time the brain is depicted accurately. This is Christopher Wren's drawing… He later on became a sometime architect as you might see if you look to your left when you leave this building.

Now, this perception, what is going on, we have got all this image from the eyes, and we talk about images in the brain. Well, we cannot have images in the brain because if we had images in the brain we would need somebody to look at them, the master controller. Now, those of a certain generation remember the Beezer, as it was drawn by Malcolm Judge, so the man himself, the body, is completely unaware of all this process that is going on here, and information is coming in and it is being sorted out by the numskulls for him, and he has, the man, has no ability of free thought or action – it is all decided for him by Brainy, who punches it in there, and the actions then occur by the man, after it has all been synthesised with all this information with these numskulls running around in his brain.

Our perception, as I have alluded to you before, does not identify this outside world as it really is. All we are doing is imagining what it really is, and we imagine it through our senses. It is a little hard to get this, I know, but as I have told you before, photons of light are converted into an image in the retina and then transmitted, digitally, to the brain, where they go through billions of analogue computers to be processed to make the visual see.

Vibrations are converted into sounds. They are not sounds – they are vibrations. They become sounds when the human being or the animal converts them into a perception.

Chemicals are just chemicals, unless they hit your taste buds, when we make them into good red wine. Smell, lovely cheeses… Actually they are just chemicals out there. They only become real things when a real human being interacts with them.

This became apparent when this gentleman here, Panizza, examined the brain of a stroke victim and realised it was in the visual cortex.

This is the Battle of Antietam, where General McClellan confronts Lee's army of Northern Virginia, and he confronts them at Sharpsburg. They cross over this bridge and, on this particular flank, the left hand flank, they face a bunch of excellent, battle-hardened soldiers, and a lot of these people are recruits, including Private Patrick Hughes, who is shot through the head at close range using this smooth-ball musket, one like this smooth-ball musket at the top, and he has a big hole in his head. He drags himself away and miraculously survives, and this eventually heals over. He does not get sepsis or anything. He is then examined eight years later by Dr Keen and Thomson in New York, where they notice that, every time he coughs, a bit of the brain pulsates out. He says, "I am blinded in my right eye," he says. "However, whisky affects me as normal and my sexual power is undiminished." So, they then examined his visual field, and what they found was something astonishing: they found out that he was missing one-half of his vision – not one eye…one half of his vision was missing. This proved that Newton was right. The half of the world on our right side goes to the left side of the brain, the half on the right goes to the left, and this was proven by this experiment.

Later on, it becomes localised by the Japanese, in the Russo-Japanese war. These are much more high velocity, smaller, make much more precise injuries than a musket ball, so you can localise very much what is going on in the brain, and what turns out is that, if this is the half of the visual field, this little bit in the middle here, which we use for central close-vision reading, recognising faces, takes up way over half of this bit of the brain, which is the visual cortex at the back, so there is a massive magnification.

We now know even how this is wired up because we can use staining between the two eyes. So the two eyes are kept separate at this stage here. The dark brown is from the left eye, the light brown is from the right eye, and this occurs in adjacent columns, where we look at different orientations of lines, and how these lines orientate depends whether these cells fire or not, and this gives us a lot of information about what is happening about moving images on our visual world, and constructing this in a variety of different ways. This area is the first processing, where we are extracting out lines and shapes; we then process it into motion and stereo, into form and into colour; and then it goes on to be combined altogether, and then we get a very rich model of what is happening out there.

It is a model. It is not the real world. We know it is not the real world from a series of visual illusions. This is one that particularly astonished me the other night at a dear friend of mine's 70th birthday party, when we staggered outside to see this enormous yellow-brown moon arising from the horizon, very similar as Van Gogh has just painted it here, probably the same time of day. However, unfortunately, the moon is not like this.

That is the real moon. It is about the same size as the clock. In fact, the real moon, when you look at it, is always smaller than you imagine it, and even if you know that and you measure it, to be truthful, most people think it is about the size of seven or eight figures held at arm's length. It is actually half the size of your little fingernail. Even though you know that, these beautiful moon illusions exist, for which we do not know why. It might be a crowding effect, it might be an angular effect – there is a lot of debate.

The Poggendorff Illusion, which was sent to him by accident as part of this illusion, we think that this is what is happening. Actually, we are wrong. If I make it transparent, this is what is happening. This is predictable. It happens every time. You cannot fake it. In fact, you can measure it. In fact, you do not even need a border to do it. You can do it with a non-existent border. Many people, with this illusion, can see this central area being much brighter than the area on the other side of it. It may be difficult to project, but you can play with this at home. But there is no border here, and when you draw this in, you ask people what on this side, where would it be, and they put the red dot, and then you can measure this distance between the red and the blue and you can work out lots of mathematics about what the angle is. There is no illusion her because this illusion has been deliberately done, and then you do not get the effect – people are very accurate where they put it. So why would we have this?

Why do we have, on the Union Jack, this illusion? A lot of people look at the Union Jack and think it's perfect. Well, it is not! It is deliberately imperfect to make it look perfect.

We look at this illusion, and we think that things are brighter on one side and darker on the other, and this is because there is a gradient here. If we hide the gradient, they both look the same.

We can actually create movement where there is no movement. This is a still image.

So I hope I have convinced that what' is going on out there is not what is reality at all! We need to visit Bishop Berkeley again. We also need to visit – some things are very powerfully retained, like faces.

This face looks a little bit odd. It is odd when it has not been adulterated as well, but essentially, what has happened is, is that the mouth here is upside down and the eyes are upside down in this image. If we rotate this image to put the eyes the right way up and the mouth the right way up but the face the wrong way up, we end up with something that is really quite extraordinary…

Using various illusions, artists have been able to create a beautiful sense of space to make buildings like this look realistic. Without their illusions in them, it would look as if it was falling down, and it would look thin here and fat there, and these optical illusions have been described in some detail in a previous lecture, which I will refer you to.

So, remember Bishop Berkeley, we said:

"There was a young man who said "God
Must find it exceedingly odd
To think that the tree
Should continue to be
When there's no one about in the quad."

"Dear Sir: Your astonishment's odd;
I'm always about in the quad.
And that is why the tree
Shall continue to be

Since observed by,
Yours faithfully, God.”